WATER ANALYSIS

AS IT SHOULD, AND AS IT SHOULD NOT,
BE PERFORMED BY THE

MEDICAL OFFICER OF HEALTH

WITH ILLUSTRATIONS

BY

CORNELIUS B. FOX, M.D., M.R.C.P. LOND.

Medical Officer of Health of Central and East Essex, Fellow of the British, and Member of the Scottish Meteorological Societies;

AUTHOR OF "OZONE AND ANTOZONE:" "WHERE—WHEN—WHY—HOW—IS OZONE OBSERVED IN THE ATMOSPHERE?" ETC.

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PREFACE.

The following paper was read by me, in the Public Medicine Section, at the Meeting of the British Medical Association, held at Norwich in August, 1874, to the principal Medical Officers of Health throughout the country, who, in a discussion that followed, endorsed its recommendations.

It was not written for the instruction of *dummy* or *pseudo* Medical Officers of Health, who receive £5 or £10 a-year as a salary, with the understanding that they are to do nothing.

It was written: (1) for the purpose of inducing all *real* Medical Officers of Health to adopt some one reliable method of Water Analysis, so that the results of the examinations of all might be comparable; (2) to demonstrate to them the superiority of the Nessler process to any other; and (3) to give to them some of the results of my experience in the examination of potable waters.

In order to make the paper useful to Sanitarians in general, several additions have been made to it, so as to render its contents a digest or *précis* of the most approved, and most rapid, reliable method of water analysis.

C. B. F.

Chelmsford, Essex,

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WATER ANALYSIS:

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MEDICAL OFFICER OF HEALTH.

Introductory remarks.

THE elementary principles on which the greater part of the work of the Medical Officer of Health is based, may be truly said to be the prevention of water pollution, and of air pollution, with the products of decomposing filth. The examination of drinking waters forms a very important portion of his duty in his crusade against preventable disease. He should not only be prepared to answer such a question as "Does a water contain a deleterious amount of organic matter?"; but should be able to reply to such interrogations as "Is this water wholesome and good?" "Which of several specified wells furnishes the purest water?" &c. I am disposed, with Mr. Wanklyn, to insist upon a high standard of purity for drinking water, and to echo the words of Mr. Simon, who, in his Second Annual Report to the City of London, observes that we cannot expect to find the effect of impure water always sudden and violent. The results of the continued imbibition of polluted water are indeed often gradual, and

may elude ordinary observation, yet be not the less real and appreciable by a close inquiry. In fact, it is only when striking and violent effects are produced that public attention is arrested; the minor and more insidious, but not less certain evils, are borne with the indifference and apathy of custom. Although no sickness may be produced during the life of a man by the habitual use of an impure water, yet there can be no question but that impure water, like impure air, affects the physique of individuals, and tends to the degeneration of a race. Nearly every water contains some organic matter which, however, in exceedingly minute quantities is harmless, as far as our knowledge extends. When its amount in a water exceeds a certain limit, it is unwise to drink the water. If it is present in still larger quantities, the drinking of such water is attended with risk or even with danger.

Delusions of the public.

Some may triumphantly observe, that they have been endangering their health during a great many years, and are not to their own knowledge at all the worse for the filth that they have taken with their water. They conclude, therefore, that impure water, like tea, which the old woman of ninety was informed was a stealthy poison, must be exceedingly slow in its action. When will the public learn, that what is food for one is poison for another; that some constitutions are susceptible to a disease to which others are quite insusceptible; that the susceptibility, when it exists, may only manifest itself at certain ages or periods in a life, or even times of the year; that a person may at one time be susceptible to a disease, and at another time be insusceptible? What egregious folly then is it for a man to argue that, because he has drank filthy pond water all his life, and fancies that he has never suffered thereby, therefore such water is not injurious to health, when we physicians can demonstrate that it will often produce fatal diarrhœa. Because pond water does not *always* cause such disastrous results to *all*, such a man will argue

that it can *never* do so to *any*. We know much, but we have yet much to learn as to the influence of impure water on the health of those in whom it does not produce disease. The study of this subject forms part of the greater one, as to the *modus operandi* of various climates on the health and character of men and animals. The possessors of the little knowledge that is well known to be dangerous, instead of displaying their ignorance by railing with presumption at what they do not understand, should learn all that is known, and then endeavour to add to the stock of our knowledge with humble, reverent, and studious minds. We cannot be surprised at the prevalence of such delusions amongst the ignorant public, when we find the mind of the intellectual public, represented by such men as Professor Tyndall, led away by the imagination into erroneous conclusions, and dogmatizing thereon to support Darwinian views, these conclusions being based on a knowledge of only *half* the truth. Because a very able physician (who has lived in the suburbs of a city the greater part of his life), whose attention has been more directed to typhoid fever, as propagated through the conveying powers of sewer gas and sewage polluted water, poisoned by some pre-existing case of fever, than to any other mode of its production; because such a man has written an excellent and logical treatise showing that all cases which he, as a town resident, has encountered, were directly traceable to some previous case, and that the supposition of the spontaneous development of such a fever rests, in his opinion, on negative evidence—the Professor, indeed, jumps to the conclusion in support, be it remembered, of his own materialistic views, that the typhoid poison cannot be spontaneously generated. The majority of the practising medical men in this country and America, backed by the greater number of the Medical Officers of Health in rural districts, who possess the *whole* truth and not the *half* truth, know that the poison

of this fever is sometimes generated in circumstances where every effort to trace a pre-existing case has been made and has failed. They believe that the poison of this fever is in all probability sometimes produced in association with the decomposition or fermentation of animal organic matter which is undergoing some unknown changes, especially when drinking water is polluted therewith, and that *one* of the great means at our disposal for the prevention of typhoid fever is to furnish the public with water free from an excess of animal organic matter.

Four methods have been employed by different Medical Officers of Health throughout the country, in their attempts to pronounce on the quality of a water. The practice of these methods has led, I am compelled to add, to most contradictory results.

Most popular tests for organic matter in water.

1. By noting the presence or absence of any smell in the air with which the water has been violently shaken.
2. The Permanganate of Potash Test.
3. The Horsley Test.
4. Nessler Test.

Smell of water.

1. *Smell of Water.*—The most rough-and-ready way that has been employed for ascertaining whether or not a water is polluted with organic matter, is to partly fill a clean bottle with a sample of it, and, having violently shaken the same, to take a hearty sniff at the air of the bottle which has been agitated with the water. If the air smells sweet and fresh, the absence of an injurious amount of organic matter is inferred, and *vice versa.* There is no doubt but that much may be learnt in this way by those who do not blunt their sense of smell by smoking, especially if they frequently practise this primitive test. It is very easy to distinguish thus between river water and spring water; and a very impure water, which may exhibit no fault to the eye, may frequently disclose to the olfactory nerves the fact of its pollution. It

should be borne in mind, however, that the existence of an unpleasant odour or taste about the water from a well sunk through clay, is no proof of the pollution of that water with organic matter. Water, if allowed to remain long in contact with certain kinds of clay in some situations, acquires such an objectionable smell as to be sometimes quite undrinkable, and yet may not, at the same time, contain an amount of organic matter that would warrant its condemnation. A well of this kind can be made to furnish excellent water by the frequent withdrawal of its contents, or, if that is not practicable, by the filling up of the dug portion of the well, and by drawing the supply solely from the bore pipe. In this way the water is prevented from lying long in contact with the sides of the well. The clay contains in some situations little nodules of iron pyrites, *i.e.* sulphide of iron, and fossils of the same composition. They possess a peculiar odour, which they give forth, especially when wetted and rubbed. This odour seems to be in some cases communicated to the water, and reminds one of sulphurous acid and occasionally of fennel. Other waters from the clay have a decided smell of sulphuretted hydrogen gas, and become turbid on standing, in consequence of the separation of sulphur. Books tell us that sulphuretted hydrogen is generated from the decomposition of water and iron pyrites. Before this gas is produced, I think, with Mr. Slater, that a partial decomposition of sulphide of iron probably occurs with a formation, by oxidation, of sulphuric acid. This acid acts then on the remaining sulphide of iron, evolving sulphuretted hydrogen gas.

"Brackish" waters.

"Rotten egg" waters.

2. *Permanganate of Potash Test.*—A second mode of testing the purity of a water has been to mix with it a minute quantity of permanganate of potash, or Condy's fluid. By this process, which is a very fallacious one, the majority of the Health Officers throughout the country judge of the amount of organic matter in water. The common practice is to add a solution

Permanganate of potash test.

of permanganate of potash to the water in question. If the pink colour of the solution is replaced by a brown tint—if, in fact, this salt is deoxidized in a greater or less space of time, it is inferred that the water contains more or less organic matter. Dr. Frankland and Mr. Wanklyn have both shown the uselessness of this permanganate of potash test; but it is, notwithstanding, still employed, and often with misleading results. In a "Report of the Analytical Sanitary Commission on Disinfectants" (*Lancet*, August 9th, 1873, p. 194), this fact is referred to. The writer, however, adds that the fallacious indications of this permanganate of potash test "has led to the total disuse of the old method of testing water." If this result had been attained, I should not now be warning my brother Health Officers against this process, which has become obsolete amongst professional analysts. Scientific chemists well know that this salt does not oxidize albuminous matters; and to this fact its failure, as a test for the organic matter in water, may doubtless in part be attributed. Without entering into chemical details, it may be said: (1) that it *sometimes* fails to afford any indication of the presence of organic matter in water that may contain a large quantity of it; and (2) that it is not sufficiently sensitive. If I prove these statements, it will, I think, be admitted that ample evidence has been afforded to warrant the assertion that the permanganate of potash test should not *solely* be relied on for determining the amount of organic matter in water. I was asked some time ago to examine the water from a well, the purity of which was questioned, the result of the analysis being a matter of the greatest moment, involving as it did important interests. It was collected by the Inspector of Nuisances in a perfectly clean bottle supplied by myself. The permanganate of potash test gave no indication whatever of the presence of organic matter, although allowed to act on the water for different periods of time. On making

Not relied upon by analysts.

Failures and errors.

a quantitative analysis of the water, by means of the Nessler test to the distillate, the following result was arrived at :—

Date.	Nessler Test.		Permanganate of Potash Test.
1873.	Parts per Million. Ammonia.	Parts per Million. Albuminoid. Ammonia.	
Sept. 3	·02	·36	No change.
Dec. 15	·03	·42	No change.

		Parts per Million. Ammonia.	Parts per Million. Albuminoid Ammonia.
For comparison.	London Water Supply (Thames) ..	0·01	0·06
	,, ,, ,, New River ..	0·00	0·06
	,, ,, ,, Kent Company	0·01	0·02
	Very bad water—Thames Water at London Bridge	1·02	0·59

Here, then, is a water, containing between four and five times more of organic matter than the maximum quantity permissible in drinking water, yielding no change with permanganate of potash. The analysis of December shows an increase in the degree of pollution of the water. The permanganate of potash neither indicated the increase in the amount of impurity, nor, indeed, the presence of *any* organic matter. The following case recently occurred in one of the south-western counties, which has utterly shaken the confidence of the local public in their opinion of their Health Officer. Two waters from neighbouring pumps, which were open to some suspicion, were examined by him. The water from one pump was pronounced to be pure, and the water from the other was declared to be impure and quite unfit for drinking purposes. It was ultimately discovered that both pumps derived their water from one and the same well. Such a lamentable mistake could not have been possible had the Nessler process been employed. Dr. Parsons refers, in a "Memorandum on Water Analysis" contained in *Public Health*, of June 16th, 1874, to an interesting case, which

shows the unreliability (if I may coin a word) of the permanganate of potash test. He writes: "I have had to examine a sample of water upon which suspicion fell, from the fact that five persons who drank it were taken ill, at the same time, with enteric fever. The owner of the well refused to believe that the water could be in fault, because it was clear, and had no unpleasant taste or smell, and because he had tried it with Condy's fluid which had kept its colour. Nevertheless, on analysis, it yielded the following large amounts :—

Grains per Gallon.	Parts per Million.	
Chlorine.	Ammonia.	Albuminoid Ammonia.
11·5	6·00	1·08

On examining the well it was found that the cesspool of a privy had overflowed into it."

Rules for the employment of the test.

The rules that guide those who rely on the permanganate of potash test are the following: "If decomposed organic matter be present in a degree hurtful to health, the pink colour is changed to a dull yellow; or, if a still larger quantity exists in the water, the colour will in time entirely disappear. Where the colour is rendered paler, but still retains a decidedly reddish tinge, then, although putrefying organic matter is present, it is so in such minute quantities as are not likely to be immediately hurtful. The quicker and more perfect the decoloration of the water tested, the greater is the quantity of decomposing organic matter present."

Objections to its use.

Permanganate of potash is not only decolourized by some kinds of organic matter, but also by salts of iron, nitrites, and hydrosulphuric acid. Iron salts, as every one knows, are often found in waters even from deep wells. Nitrites are sometimes found in the purest waters, *e.g.*, the Grays

water of Essex. Dr. Parsons writes: "The permanganate of potash test is, I find, as tedious as the ammonia process, while the shades of colour, from their dissimilarity in kind as well as in degree, are far more difficult to compare than those of the latter process." It must be admitted by all that the permanganate of potash is not sufficiently sensitive when it fails to make any distinction between such waters as the following:—

Nessler Test.		Permanganate of Potash.
	Parts per Million. Alb. Ammonia.	
Wickford Village. Artesian well, 385 feet in depth. Water employed by majority of villagers, and of the neighbouring farmers.	·04	Pink colour is paler, slight brick-red sediment.
Great Baddow. In which diphtheria has been present. Well at back of schools, 14 yards from a cesspool. Gravelly porous soil.	·28	Pink colour remains, but is paler; very slight brick-red sediment.

In the subjoined analyses, the permanganate of potash positively leads us into the error of supposing that the offensive and impure water is purer than the artesian water which is of the highest excellence.

	Parts per Million. Alb. Ammonia.	Permanganate of Potash Test.
Well at Galleywood, close to heaps of decomposing filth. Water complained of by cottagers as somewhat offensive to the smell.	·24	Pink colour remains.
Stagg's Artesian well, Burnham.	·03	Has become very pale; rather copious brick-red sediment.

The Medical Officer of Health of the Goole and Selby Sanitary Districts very properly remarks, with reference to the permanganate of potash test: "Should decoloration occur, it does not follow that it is due to sewage contamination; nor, on the other hand, if the colour be permanent, does it always prove that the water is pure."

Fever at Ingatestone.

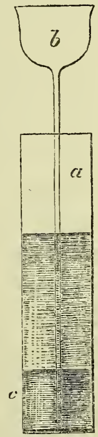
Enteric fever broke out at Ingatestone, and was confined to the market place. Being temporarily prevented from analyzing waters according to the Nessler process, I tested that of the public well, around which the fever was confined, with a solution of permanganate of potash, and found no indication of impurity. The fever still spreading, notwithstanding the disinfection of the drains with carbolic acid and the adoption of the other customary measures in such cases, I analyzed the water by testing the distillate with the Nessler solution. Finding it impure, I advised the Rural Sanitary Authority to order the well to be closed, which was accordingly done. The cottagers were directed to a pure water supply, and the fever speedily disappeared. I subsequently ascertained that a rotten drain passed within two yards of the well. This case convinced me of the folly of trusting to the sensitiveness of permanganate of potash test.

Horsley test.

3. *The Horsley Test.*—This test consists in the addition of a minute quantity of pyrogallic acid to a little of the water to be examined; a small quantity of pure sulphuric acid is then introduced, by means of a funnel tube, underneath the water; and, finally, the smallest bit of common salt is dropped into the mixture. The layer of sulphuric acid assumes a dark lilac or black colour when a water contains much nitrates and nitrites, and remains colourless when twice distilled water is employed. This test solely indicates the amount of nitrates and nitrites in a water, and therefore affords no indication of the presence or absence of organic matter. There are waters, such us that of the South Essex Water Company,

which contain an abundance of these salts, and an amount of organic matter which is so small as to exhibit a marvellous purity. A water from a public well in my district, of universally acknowledged excellence, yielded with this test a very dark lilac colour—an indication of great impurity. On analysis, it proved to possess only ·08 part per million of organic matter.

Fig. 1.



a. Test glass.
b. Funnel tube.
c. Layer of sulphuric acid.

Nitrates are produced by the oxidation of nitrogenous organic matters that find their way into water, and are also derived from certain geological strata.

Some one has very properly said that, if the nitrates in these pure waters ever came from organic matter, it is now *fossil* organic matter, in other words, the organic matter of past ages.

The presence or abundance of nitrates and nitrites in a water affords no indication, therefore, of the defilement of the same, nor does an absence of these salts prove the absence of pollution.

4. *Nessler Test.*—The principle of the Nessler process consists in the measurement of the amount of nitrogenous organic matter, by the estimation of the quantity of ammonia furnished by the destruction of the organic matter. Some consider that it is only sufficient to add a small quantity of the Nessler test to the water to be examined for organic matter, and that the depth of the milky-brownish tint produced exhibits the amount of impurity. The Nessler test is simply a test for ammonia, and is not a test for organic matter until that organic matter has been converted into ammonia, by boiling it with permanganate of potash and a large excess of caustic potash. Nessler test.

Distillation of the water to be examined for ammonia

adds to the delicacy of the process, for ammonia admits of concentration, and minute quantities are more visible in a small quantity of water than in double the amount. Distillation, moreover, by the separation of the salts in a water, such as carbonate of lime, &c., prevents the milkiness, created on the addition of the Nessler reagent, which interferes materially with, if it does not altogether prevent, a correct estimation of the quantity of ammonia contained in a water. The knowledge of the amount of ammonia in a water is of little interest without an estimation of the quantity of organic matter associated with it. Ammonia is harmless, and may be abundant in a water which is perfectly pure.* Combined, however, with a knowledge of the amount of organic matter in a water, the proportion of ammonia, and the manner in which it passes off in distillation, is of great importance and interest. For example, whilst recently examining a water, which to the eye presented an appearance of great purity, I found that an *enormous proportion* of *ammonia* distilled off into the *first distillate*, and that an excess of organic matter existed in conjunction with it. This examination told me that the water was polluted with urine, which opinion was found to be correct, as the drain from a urinal was discovered to be leaking into the well from which the water was collected.

Knowledge of amount of ammonia in a water of little value, unassociated with an estimation of amount of organic matter.

Detection of urine in drinking water.

The estimation, likewise, of the amount of chlorine in a water is in some circumstances worth little in itself unless we know the amount of organic matter contained in it. The determination of the amount of chlorine in the water of a district, where an excess of chlorine does not occur in all waters, is an indirect guide as to whether or not the water is contaminated with sewage. Urine and sewage contain a large

Observation as to amount of chlorine of little value, unaccompanied by calculation of quantity of ammonia and organic matter.

* *Vide* Mr. Wanklyn's opinion, which is shown to be a mistaken one. Pages 18 and 19.

amount of chlorides. The presence of 5 or 10 grains of chlorine per gallon in a water is a suspicious circumstance in such localities. Good natural waters contain, on an average, from ·7 to 1·2 grains per gallon.

Waters from the green-sand formation, and from the London clay, contain generally an excess of chlorine, derived from the chloride of sodium and other salts of chlorine in the sand. The waters of the county of Essex, which come from layers of sea-sand and clay containing marine fossils, possess as a rule a great deal of chlorine. One water which I examined recently in Essex, contained as much as between 74 and 75 grains per gallon. If a sample of water contains an amount of chlorine below the average in the district, the probability is that there is no sewage contamination. If, on the other hand, an excess of chlorine is accompanied by an excess of albuminoid ammonia and ammonia, pollution with sewage is almost certain. The amount of chlorine in a water is also a guide as to the quantity of the salts of sodium and potassium contained in it. Let it be always remembered, then, that in all cases the estimation of the amount of chlorine and the amount of ammonia must, to possess any value as a guide to the pollution of a water, be taken in conjunction with the quantity of organic matter. Everyone who has had any experience in water analysis, is aware that the addition of the Nessler test to a water containing ammonia is attended by the production of a yellowish-brown tint, similar to that of sherry, the depth of which is measured, as it varies according to the amount of the ammonia present.

Some geological strata furnish waters containing an excess of chlorine.

An interesting question arises as to the amount of organic matter which should be considered permissible, and as to the quantity which would justify the condemnation of a water.

Permissible amount of organic matter in a water.

Wanklyn, the joint discoverer with Chapman, of the ammonia process, has been accustomed to consider the maxi-

mum amount which should be permitted in drinking water as ·08 of one part in a million. He has, however, laid down the following rules in the third edition of his work, just published, relative to the amount of organic matter which is allowable in potable waters. He writes: "If a water yield ·00 parts of albuminoid ammonia per million, it may be passed as organically pure, despite of much free ammonia and chlorides; and if, indeed, the albuminoid ammonia amount to ·02, or to less than ·05 parts per million, the water belongs to the class of very pure water. When the albuminoid ammonia amounts to ·05, then the proportion of free ammonia becomes an element in the calculation; and I should be inclined to regard with some suspicion a water yielding a considerable quantity of free ammonia, along with ·05 parts of albuminoid ammonia per million. Free ammonia, however, being absent, or very small, a water should not be condemned unless the albuminoid ammonia reaches something like ·10 per million. Albuminoid ammonia above ·10 per million begins to be a very suspicious sign; and over ·15 ought to condemn a water absolutely."

My experience is quite in harmony with nearly all here stated. I cannot agree with Mr. Wanklyn in looking with suspicious eyes at a water yielding a considerable amount of free ammonia, along with ·05 parts of albuminoid ammonia per million.

Waters renowned for purity which contain an excess of free ammonia.

Here, for instance, are the analyses of three waters, all from deep artesian wells situated in a little village:—

	Parts per Million.	
	Free Ammonia.	Alb. Ammonia.
A. Depth 385 ft. ..	·59	·04
B. Very deep. ..	·41	·07
C. Depth 330 ft. ..	·37	·06

Here are analyses of waters of another village, possessing locally a high repute for purity :—

	Parts per Million.	
	Free Ammonia.	Alb. Ammonia.
A. 250 ft.	·76	·04
B. 300 ft.	·74	·03

An excess of free ammonia when associated with a permissible amount of albuminoid ammonia may be due either—

Possible causes of the presence of an excess of ammonia in waters.

1. To vegetable impurity;
2. To entrance of rain water into well;
3. To the beneficial transformation of harmful organic matter into the harmless ammonia, through the agency of sand, clay, and other matters, which act on the water in a manner similar to the action on it of a good filter;
4. To some salt of ammonia existing in the strata through which the water rises; or,
5. The free ammonia may be produced, as Mr. Slater suggests, by the reduction of nitrates by the sulphide of iron contained in the clay.

Wholesomeness of a water.

With reference to other questions which Health Officers should be prepared to answer, such as, "Is my drinking water wholesome and good?", "Which, of several specified wells, all situated perhaps in one village, furnishes the purest water?", I may say that it is necessary, in order to answer them, to ascertain not only the amount of organic matter in a water, but the total quantity of solid residue, and the degree of hardness. Physicians well know that a water containing a moderate quantity of salts (medicinal waters administered with a specific object, and for a limited period only, are, of course, excluded from consideration) is

Saline matters in excess.

better than one containing an excess; for the constant imbibition of fluids, strongly impregnated with saline substances, tends to diminish the richness of the blood, and to render some people anæmic. Although the waters from the artesian wells in Essex contain, as a rule, a very minute proportion of organic matter, yet they hold in solution a large quantity of salts, derived from sand beds beneath and sometimes alternating with strata of the London clay. These waters, containing as they do so large a quantity of saline matters, cannot be considered so wholesome as land springs, equally free from a deleterious amount of organic matter. I have often seen the ill effects of the continued employment of waters rich in saline matters. Some well waters have been found to contain an enormous proportion of salts. I once analyzed a water from an artesian well which held in solution 341 grains of solids in each gallon, and another water possessing the large amount of 485 grains per gallon. Sea water holds in solution solids to the amount of between 2,400 and 2,700 grains per gallon.

Spring water of the best quality usually contains about 14, 17, 18, or 19 grains per gallon of solid residue. The maximum limit of solid residue permissible is from 30 to 40 grains per gallon, but waters containing a larger amount are in certain cases permissible if the salts are quite harmless.

Purgative waters.

Some wells contain water so purgative as to preclude the possibility of employing them as a regular water supply. I have met with many waters of this kind in Essex. They contain sulphate or carbonate of magnesia. I look upon them in this county, which contains so much ague, such a large amount of liver disorders, hæmorrhoidal and other malarial affections, as mineral waters of some value. Containing, as they do, not only a purgative salt, but a large proportion of other saline matters, they are not wholesome waters for general and constant use. In localities where these

mineral waters exist the people are, for the most part, compelled to drink pond water. Malarial affections are often traceable to the employment of pond water for drinking purposes. These aperient waters may be regarded as in some sense the remedy to counteract the effects of the poison, for they are, in all probability, of great service in congestion of the liver and in hæmorrhoids, by relaxing the portal system of vessels.

Hardness of waters.

The degree of hardness is a matter to be considered in pronouncing on the wholesomeness of a water. We all know the intimate relationship between calculous disorders and the consumption of waters containing an excess of lime. The production of goître and cretinism, and its connection with the supply of hard waters, is a matter of the greatest interest and certainty. Dr. Murray, of Newcastle-upon-Tyne, gives us * a terrifying description of the evils resulting in the limestone district in which he lives, from the supply of very hard waters. Good waters average between 11 and 16 degrees of hardness. A hard water, quite free from any purgative salt, will in some persons produce diarrhœa. Some deep artesian wells, made in the London clay, extending to the sand beds lying underneath, furnish water that is excessively soft, so that they render tea very black, and are consequently highly approved of by the fair sex. Pipeclay, mixed with sea water, is well known by marines to soften it, and increase its cleansing properties, by virtue, I presume, of the action of the alumina of the clay on the salts held in solution.

Let me describe, in as few words as possible, the Nessler process, and give a digest or *précis* of a complete analysis as practically carried out, freed altogether from lengthy and

* "On the Influence of Lime and Magnesia in Drinking Water in the Production of Disease."—*British Medical Journal*, Sept. 28th, 1872.

technical details. I will first enumerate the apparatus and chemicals required.

Apparatus.

Retort holding about $2\frac{1}{2}$ litres; Liebig's condenser; Nessler glasses (8); bell metal clamps (2); burette, graduated to $\frac{1}{10}$ths, and capable of holding 50 c.c., and stand; pipette; adapter; retort stand; half litre flask; 70 c.c. flask; 25 c.c. flask; scales which will turn with a milligramme, and weights from a milligramme to 20 grammes; Nessler reagent; platinum dish; beaker; Bunsen's burners, one large and another small; white porcelain tiles, about 5 inches square (2); Gmelin's wash bottle; stoppered bottles, each holding about one litre, for collecting waters; Berlin evaporating dish, 4 inches in diameter; pipette for silver solution, of the capacity of 5 c.c., and graduated to $\frac{1}{10}$ths; ditto for soap solution; glass rod; pipe triangle; dilute standard ammonia solution,

Chemicals.

permanganate of potash and caustic potash solution, nitrate of silver solution, soap solution (*for Recipes, see Appendix*), distilled water, sulphuret of ammonium, chromate of potash, hydrochloric acid. It is wise to purchase all the above articles, and to oneself prepare the distilled water and the solutions. The latter, however, can be bought, if it is wished to avoid the trouble of making them.

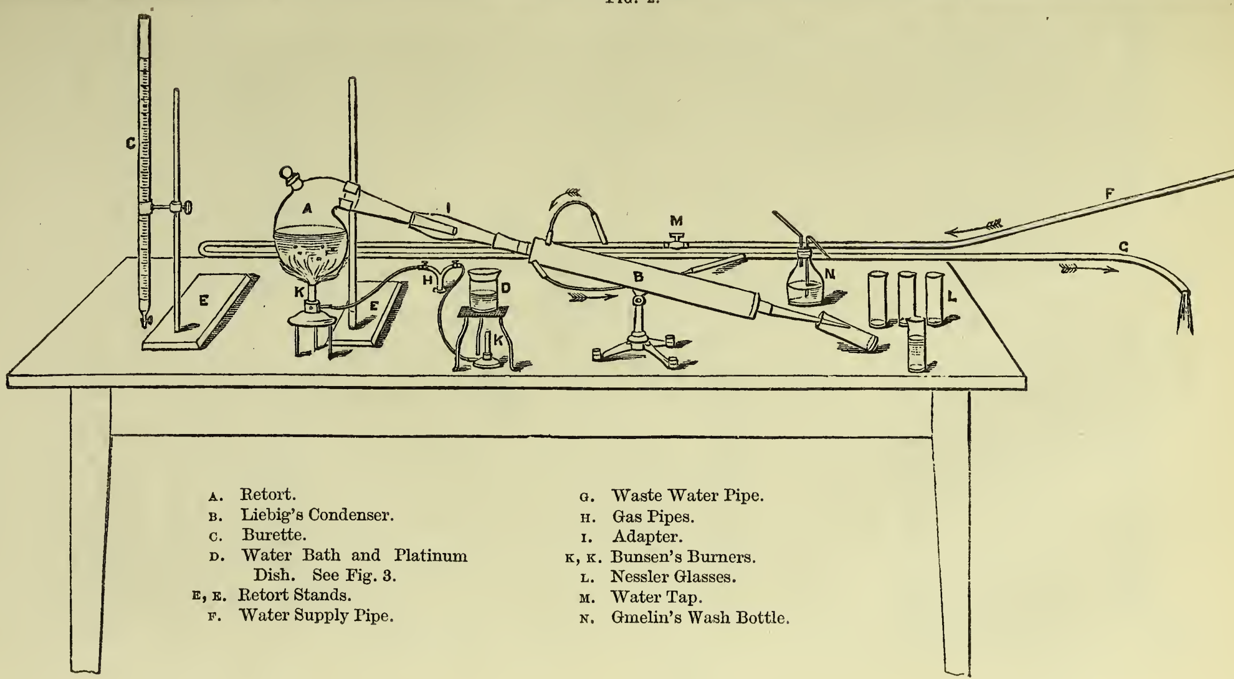
I procured my apparatus and Nessler reagent at Messrs. Townson and Mercers, of Bishopsgate Street; my excellent chemical balance, made by Becker of New York, at the office of the "Chemical News," for £3 13s. 4d.; and the weights of Oertling.

Solid residue.

Solids.—If it is the intention to make a complete analysis, which would necessitate the estimation of the amount of solid residue, commence thus:—

Weigh the platinum dish empty, place it over a water bath, and pour into it 25 c.c. of water to be examined. Evaporate to dryness. Again weigh dish promptly to avoid deliquescence of salts.

Fig. 2.



A.	Retort.	G.	Waste Water Pipe.
B.	Liebig's Condenser.	H.	Gas Pipes.
C.	Burette.	I.	Adapter.
D.	Water Bath and Platinum Dish. See Fig. 3.	K, K.	Bunsen's Burners.
E, E.	Retort Stands.	L.	Nessler Glasses.
F.	Water Supply Pipe.	M.	Water Tap.
		N.	Gmelin's Wash Bottle.

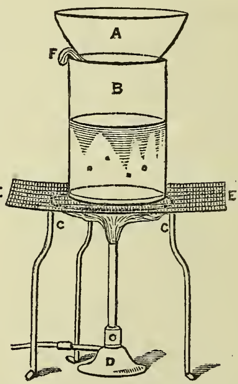
For example :—Dish and residue	.. ..	26·240 grammes.
Dish	.. ..	26·232 „
Weight of residue	.. ..	·008 „

It was formerly the practice to evaporate 100 c.c. to dryness, but time is saved by employing a smaller quantity of water. As 25 c.c. are a quarter of 100 c.c., multiply the result by 4 and then, to arrive at the number of grains per gallon, multiply by ·7 thus :—

$$\begin{array}{r} \cdot 008 \\ 4 \\ \hline 32 \\ \cdot 7 \\ \hline 22\cdot 4 \end{array}$$

The water contains 22·4 grains per gallon.

Fig. 3.



A. Platinum Dish.
B. Beaker containing Water.
C. Tripod Stand.
D. Bunsen's Burner.
E. Coarse Wire Gauze, on which a pipe triangle rests to support the beaker.
F. Thick bit of Paper between Dish and edge of Beaker, to permit of escape of steam.

Whilst the evaporation is going on, make the following examination :—

Ammonia and *Alb. Ammonia.*—Wash out by means of the wash bottle the glass tube of the Liebig's condenser with a little distilled water. Place a half litre of the

water to be examined in the retort. Distil over into a Nessler glass 50 c.c. Add to distillate 2 cubic cent. of Nessler test. If it contains ammonia a yellowish-brown colour is produced; the deeper the colour, the more ammonia is contained in it. Imitate the depth of tint by mixing in a Nessler glass with 50 c.c. of distilled water, more or less of the dilute standard solution of ammonia contained in the burette, and add to it 2 c.c. of Nessler test. Wait always about three minutes for the colour to be developed. If the tint of dilute standard of ammonia be too light or too dark, make up a fresh standard containing less or more ammonia, as the case may be. Treat the 2nd, 3rd, and 4th 50 c.c. that distil over in a precisely similar manner. We have now 300 c.c. of water left in the retort. To convert organic matter into ammonia, add 50 c.c. of the permanganate of potash and caustic potash solution to the boiling water. Gently shake the retort, so as to give the mixture a wavy motion, to prevent "bumping," and distil. Three distillates, each of 50 c.c., must be taken, which should be treated in the same way.

Ammonia.

Organic matter or albuminoid ammonia.

The comparison between the colour of the standard and the distillate is made by placing the Nessler glasses on the white porcelain tile, and by looking down through the columns of fluid on to the tile. The amount of the dilute standard solution of ammonia employed to match the tint of the distillate represents the amount of ammonia in the distillate.

For example, if the amount of dilute standard solution of ammonia required to match the tint of the

1st distillate be 5 c.c.
2nd ,, ,, 3 c.c.
3rd ,, ,, 1 c.c., we arrive at these figures :—

Ammonia or Alb. Ammonia	·05
	·03
	·01
Total	·09

As half a litre of water is taken for analysis, multiply the results by 2, in order to make them give the proportion for the litre. In that case the free ammonia and albuminoid ammonia are expressed in milligrammes per litre, or in parts per million.

·09 in $\frac{1}{2}$ litre =

·18 milligrammes per litre or parts per million.

It is necessary to be sure that the distilled water used for preparing the standard gives no colour with Nessler test. If it gives any colour it must be redistilled.

Whilst the distillation proceeds the amount of chlorine and the hardness should be taken.

Chlorine.

Chlorine.—Place 70 c.c. of water to be examined in an evaporating dish, and add a minute morsel of chromate of potash (pure). Then, by means of a pipette, graduated to $\frac{1}{10}$ths of a cub. cent., and filled with 5 cub. cent. of the solution of nitrate of silver, this standard should be allowed to drop into it until the red colour produced ceases to disappear. Directly the red tint becomes permanent, note the amount of nitrate of silver solution necessary to attain this point. Run a little more nitrate of silver into the water, to be sure that the water is not acid, for chromate of silver is soluble in acids. The number of cub. cent. of the nitrate of silver solution employed will represent the number of grains of chlorine per gallon.

Hardness.

Hardness.—Seventy cub. cent. of the water to be examined for hardness should be placed in a stoppered bottle, holding about 250 c.c. The standard soap solution is dropped slowly by means of a pipette graduated to $\frac{1}{10}$ths of a cub. cent. into the bottle, which is frequently shaken violently to note the

Temporary.

amount of soap solution necessary to create a persistent lather. If a water is so hard that the addition of 16 c.c. of soap solution does not produce a lather, add 70 c.c. of distilled water, and mix. Then continue the addition of

the soap solution. If the dropping of soap solution be proceeded with until a second 16 c.c. be consumed without the formation of a permanent lather, a second 70 c.c. of distilled water must be added. Suppose, for example, 13 c.c. of soap solution are necessary:—

	13
Deduct for hardness of each 70 c.c. of distilled water employed	1
Degrees of hardness..	12

To know the quantity of carbonate of lime, or other salts equivalent in hardness to carbonate of lime contained in the water, subtract 1 degree. The water just cited possesses 11 grains of carbonate of lime, or salts equivalent, per gallon.

Boil a sample of the water, and examine it in the same manner, and the *permanent* hardness is obtained. Permanent.

The entry of an analysis may be conveniently made in the note-book thus :—

Entry of an analysis in note-book.

Date, November 5th, 1874.

WELL AT WOODHOUSE FARM.

Depth, 25 feet, soil sandy.		For chlorine, 70 c.c. taken. Required of solution of nitrate of silver 20 c.c. ∴ 20 grains per gallon.
Ammonia . .	·02	For solids 25 c.c. taken.
,, . .	·01	Dish and residue 26.251
,, . .	·00	Dish . . . 26.230
	·03	·021
		4
Alb. Ammonia .	·06	
,, ,, .	·03	84
,, ,, .	·01	·7
	·10	∴ 58·8 grains per gallon 58·8
		Hardness, 19 degrees.
In litre—		
Ammonia . .	·06	N.B.—Water condemned as unfit for drinking purposes.
Alb. Ammonia .	·20	

Poisonous metals.

Poisonous Metals.—Lead and copper are usually the poisonous metals with which waters are liable to be contaminated. The former metal is far more commonly found in water than the latter. A water sometimes contains iron, which is of course not poisonous, but the presence of which is undesirable in all cases, and hurtful in some.

Place 70 c.c. of water to be examined in a porcelain dish, and stir it with a glass rod moistened with sulphuret of ammonium. Note whether or not there be any coloration. If so, it may be owing to a sulphuret of iron or lead, or of copper. If on adding two or three drops of hydrochloric acid the brown colour disappears iron is present, for the hydrochloric acid dissolves the sulphuret of iron. If, on the other hand, the colour does not vanish on this addition, lead or copper is present. It matters not which, for both are equally injurious. Wanklyn writes : "If there be coloration," on adding the sulphuret of ammonium, "it should only be just visible, and on adding two or three drops of hydrochloric acid, it ought to vanish absolutely." Water which answers to this test in a satisfactory manner is registered as sufficiently free from poisonous metals, and water which does not is to be condemned as contaminated with metallic impurity. If the quantity of either of these metals in a water be required, it is necessary to employ standard solutions of each of them (1 milligramme of a salt of each metal to a cub. cent. of water); and, if we desire to ascertain whether lead *or* copper be present, it is needful to operate on a larger quantity of water, and to work according to the directions in that distinguished chemist's exhaustive treatise on water analysis.

The above simple mode of testing for poisonous metals is sufficient for the Medical Officer of Health, for it enables him to say that a water contains less than $\frac{1}{10}$th grain of lead or copper per gallon, an amount which should condemn a drinking water.

Every water analyst should have waters collected in stoppered bottles supplied by himself, which have been thoroughly cleansed with a strong acid before leaving his laboratory.

Having estimated the amount of organic matter, of ammonia, of solid residue, of chlorine, and the degree of hardness of a water, we are in a position to answer the question as to whether the water is wholesome. It will be urged, with reason, that such an analysis as this, however desirable it may be, cannot be undertaken by the Medical Officer of Health, for so much time would be consumed in water examinations as to leave but little for other work. It is but rarely that I make a complete analysis of this kind, unless it be for a sanitary report, when the question arises as to which of two or three springs should be selected for the water supply of a village that is destitute of pure water.

Mode of limiting extent of analysis.

If the question, "Is this water wholesome and good?" be addressed to me, I immediately ask whether any illness or disease has been attributed to the employment of it. Many send a sample of their drinking water for analysis, actuated by motives of simple curiosity. I decline to examine these waters, with a polite intimation that I have no time. If there is a suspicion lest the water has interfered with the health of any person or persons, inquiries are made as to whether there is any reason for suspecting the presence of organic matter or metallic poisons, or whether the applicant finds the water too hard for domestic purposes, or whether it is brackish or purgative. In fact, I ask what reason there is for complaining of the water. In this way the extent of the analysis is limited, and the applicant obtains the information required. In the majority of cases that present themselves, the question arises as to the amount of organic matter, whether within or beyond the permissible limit.

Time occupied.

Now, what amount of time is occupied in answering this question with absolute certainty? Thirty minutes. If it is needful, as is often the case, to estimate the exact amount of organic matter present in a water, forty minutes are consumed. If a complete analysis is required, I determine the amount of chlorine in, and the hardness of, the water, whilst the distillation is going on. The evaporation of the 25 c.c. of water to procure the solid residue, and the weighing of the dish both before and after this operation, of course proceed simultaneously with the distillation. A *complete* analysis, then, of a potable water can with practice be accomplished in forty minutes.

Dr. Parsons recommends the following plan* for expediting the process:—

Modes of expediting the process.

" Make a standard solution of ammonia, containing ·05 or ·10 milligramme, as may be most convenient, in about 40 centigrammes of distilled water; add the Nessler test, make it up to exactly 50 centigrammes, and pour it into a burette. Then, to estimate the ammonia in a sample, take two glass cylinders of exactly equal diameter, and stand them on a sheet of white paper; put the Nesslerized distillate into one, and into the other pour from the burette as much of the above standard solution as will produce an equal intensity of colour on looking down through the columns of fluid from the top. More or less of the standard solution may be taken, until the shades exactly match; and in this way the tediousness of making repeated guesses, until the right strength is arrived at, may be avoided.

" If the amount of ammonia in the distillate be larger than that in the standard, a fraction of the former may be taken, or a stronger standard made up; if, on the other hand, the amount be very small, it is more accurate to pour into the second cylinder a quantity of distilled water, about equal to

* *Public Health*, June 16th, 1874, p. 184.

the distillate, and then add the standard Nesslerized solution to it, till the requisite depth of colour is attained."

My trial of this mode of performing an analysis has not led me to adopt it, as I find it troublesome. A far better mode of expediting the process is to submit for examination a $\frac{1}{4}$-litre instead of a $\frac{1}{2}$-litre of water, and to multiply the results by 4 instead of by 2. This rapid modification of the Nessler process is suitable only for the Medical Officer of Health who has had some experience in water analysis, to whom I would recommend it. Messrs. Townson and Mercer have made for me Nessler glasses of a size adapted for the examination of half the usual quantity of distillate, namely, 25 cub. cent.

My great object in bringing the subject of water analysis before the Public Medicine Section of the British Medical Association, is to induce the Health Officers throughout the country to adopt *one* process, so that the results of the analyses of all may be comparable with one another. The limits prescribed by the rules of the Association, as to the length of each paper, prevent me from referring to the purification of drinking waters. I do not think, however, that I have much which is new or strange to say on this subject. Under these circumstances silence may, equally with brevity, be considered the soul of wisdom.

APPENDIX.

RECIPES OF SOLUTIONS.

Standard Soap Solution.

10 grammes of green Castile soap is dissolved in a litre of weak alcohol (35 per cent.). One cub. cent. precipitates one milligramme of carbonate of lime.

Dilute Standard Solution of Ammonia.

Keep two solutions—a strong and a dilute. To prepare the strong solution dissolve 3·15 grammes of crystallized sal. ammoniac in one litre of distilled water. To prepare the dilute solution place 5 cub. cent. of the strong solution in a half-litre flask, and fill it up with distilled water. The dilute solution contains $\frac{1}{100}$ milligramme in each cub. cent.

Permanganate of Potash and Caustic Potash Solution.

Permanganate of potash crystallized, 8 grammes; solid caustic potash in sticks, 200 grammes; distilled water, 1 litre. Boil the above so as to thoroughly dissolve the chemicals in the water. Replace the water lost in boiling, as steam, by adding sufficient distilled water to bring it back to the litre.

Standard Solution of Nitrate of Silver.

Dissolve 4·79 grammes of crystallized nitrate of silver in 1 litre of distilled water. One cub. cent. precipitates one milligramme of chlorine.

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